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Raspberry Pi based Smart Classroom Architecture with Local Network

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ABSTRACT

Classrooms are important building blocks of a school campus. Therefore, a feasible architecture for building and running smart classrooms is essential. Today all online education system is based on the browser/server structure or client/server structure and for this system required the computer to every student. As the number of student increases cost of education also increases. In small schools and institutes could not able to afford a computer to every student. Instead, we aim to design an embedded device with only one master computer and number of slave units. Raspberry Pi has the capability of being configured as an access point and as a web server, so it can be used for creating applications reachable from mobile devices without needing an Internet connection. The proposal is based on the possibility for students to Answer questionnaires from their mobile devices. The teacher can observe answers in real time. This solution adds dynamism integrating the existing mobile devices in the classroom. It eliminates the use of computers or laptops to each student which reduces size and cost of the project. Programming language used in this project would be HTML alongwith Python, Operating System will be Raspbian and Questionnaire Software will be Node-Red. This paper explains the proposal features in terms of used hardware and software, as well as the functional tests performed and their implementation allowing replication.

Keywords — Raspberry Pi, Mobile devices, Teaching resources, Questionnaires, Node-Red

I. INTRODUCTION

New technologies are here to stay. Nowadays, they are part of our lives, simplifying some tasks and changing the way we do other ones. Changes occur in every area and pushed mainly by mobile devices, which are continuously offering us connectivity, interaction, and content that before was only available in specific places. For example, to watch a movie or a video it was necessary to be in front of a TV at home or in a cinema, to catch up with the news we needed the radio, TV or a printed newspaper. Today, those habits have changed,

and people access those contents from their mobile devices at any time and at any place.

"The rise of information and communication technology, from the TV invention to the arrival of the Internet to educational institutions, forces teachers to plan a class with something more than a blackboard, a slice, and a book. Regardless of the teaching level, including some new technologies is necessary. Whether they are wanted or not mobile technologies are part of daily activities, resolving most of our communicative and informative needs, especially for the youngest ones, who are mainly the group of students who have to be educated using resources of their daily life". "The students in our classrooms are changing, as a result of their experience with technology outside of the school, and they are no longer satisfied with an education that is not directly driven to the real world in which they live".

Raspberry Pi has the capability of being configured as an access point and as a web server, so it can be used for creating applications reachable from mobile devices without needing an Internet connection. The proposal is based on the possibility for students to answer questionnaires from their mobile devices. The teacher can observe answers in real time. This solution adds dynamism integrating the existing mobile devices in the classroom. It eliminates the use of computers or laptops to each student which reduces size and cost of the project. Programming language used in this project would be HTML alongwith Python, Operating System will be Raspbian and Questionnaire Software will be Node-Red.

This article is organized as follows: section 2 shows a literature review pointing out related articles. Section 3 explains what a Raspberry Pi (RPi) is and its features. Section 4 explains the proposal. In section 5 the steps to install the complete system are elaborated. Section 6 presents the realization of the project and functional test. Section 7 talks about relay control module. Finally, section 8 presents the conclusions and future work.

II. Literature Review

Raspberry Pi is a versatile, small and cheap single-board computer. Its hardware features and the capability of using open source software have allowed different implementations in different areas, such as education. Within this knowledge area, there are lots of researches that apply Raspberry Pi in different parts of a class, e.g. developing a "smart class", hardware for laboratory work and study, networking building and educational applications in developing countries.

Several authors approach the "Smart Class" topic. In 2001, the paper [1] was already referring to this concept integrating devices to capture audio, video, slides and hand-notes, between teachers and students. In [2], the design of an active class is addressed, in which students' do collaborative learning, using mobile devices. The paper [3], on the other hand, adds the usage of Raspberry Pi to the Smart Class concept. The article [4] shows the current state of a platform design for a smart class through mobile devices of teachers and students. The Raspberry Pi is connected to the server and the peripherals. On the other hand, [5] also shows the usage of Raspberry Pi to record classes' audio using a Bluetooth microphone and sending the files through the network, so that students can listen to the classes if they were absent, or just to review them, etc. But [6] presents the most detailed analysis on the subject with the full explanation of using Raspberry Pi for Smart Classrooms.

In all the reviewed papers, the main reasons for adopting Raspberry Pi are its versatility and low cost.

Raspberry Pi

What is Raspberry Pi

The Raspberry Pi is a low cost, **credit-card sized computer** that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing

everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

What's more, the Raspberry Pi has the ability to interact with the outside world, and has been used in a wide array of digital maker projects, from music machines and parent detectors to weather stations and tweeting birdhouses with infra-red cameras. We want to see the Raspberry Pi being used by kids all over the world to learn to program and understand how computers work.

Raspberry Pi Components

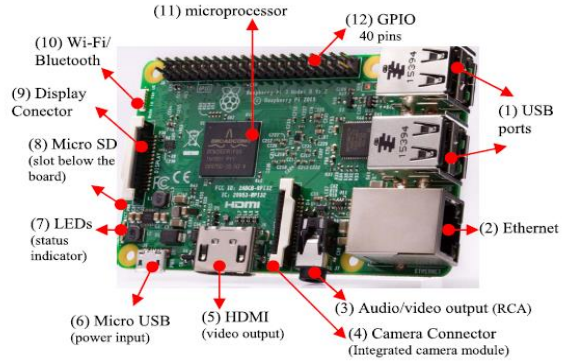

Fig. 1. Raspberry Pi 3 components.

Raspberry Pi (RPi) is a small, single-board computer (Fig. 1 shows components of the newest model the RPi 3). In this board, we can observe four small holes that allow adjusting it to a small case by using screws or other elements and it uses a 5V Micro USB power adaptor (6). The number indicated after the word adaptor is a reference in Fig. 1, we will use numbers to identify each component in Fig. 1. This power adaptor is like the ones we use to charge our mobile phones. It is also possible to improve portability by adding a portable charger. It has some LEDs (7) that turn on to give status indications (for example when the RPi is working).

It has the possibility of connecting an external projector or monitor via HDMI (5). It is also possible to connect a TV via the RCA output (3). Apart from the HDMI, which is the most common solution for connecting monitors or modern TVs, the RPi 3 can include an integrated screen (which improves portability of the solution). This screen could also be a touchscreen. The screen could be connected in two ways, using the Display Connector (9) or the GPIO (12). GPIO is a general-purpose port for input/output, any external device will be connected to the RPi by any of these pins. This port has also 40 pins, as in the previous version, and it allows connecting specific sensors (sound, humidity, temperature, etc.). For example, if the application to be developed would require a camera, this could be a USB camera (1) or an integrated camera connected directly to the camera connector (4).

The RPi 3, like its predecessor the RPi 2, continues having four USB ports (1). Regarding connectivity, it has Ethernet, as the previous version (this means it is possible to connect a network cable (2)), but the new model includes integrated Wi-Fi and Bluetooth adaptors (10); the previous version used to depend on an external USB board to provide Wi-Fi capabilities. Another important feature is that the RPi 3 has a powerful microprocessor than the RPi 2 (which had, indeed, a better processor than the previous models, 1A, AB, 1B+). The RPi 3 has an ARM Cortex-A53 64 bits quad-core processor, but it still has the same RAM memory as the RPi 2, 1 GB.

The operating system and the software will be installed in a Micro SD card (8) (operating system selection will be addressed in section 5). Although all the previous versions had a Micro SD slot, it is simpler to remove the Micro SD card in the newest model.

III. Proposed System

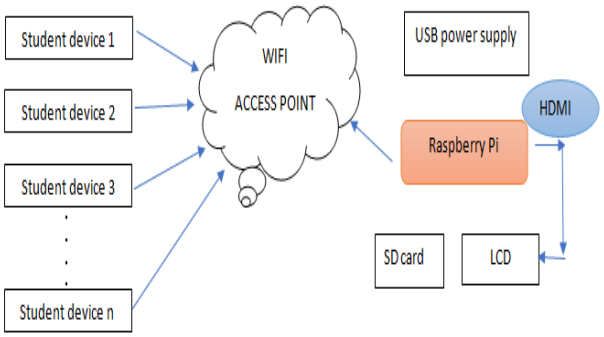

Fig. 2. Ovarall view of the proposed system

The proposal consists in using the RPi to create a centralized network where the RPi provides access point capabilities, without needing an Internet connection. RPi 3 is used to accomplish this goal because, as we can see in Fig. 1, it has a built-in Wi-Fi board. In this way, students can connect their mobile phones or other devices to the network created by the RPi. A questionnaire application is installed in the RPi allowing students answering multiple- choice questions related to the topics of the class before an exam. The traditional method, that consists of students raising their hand for the option they think is valid, is slower and more tedious. Furthermore, this traditional process has the problem that students may raise their hand because they observe that most of their classmates do that, and in many cases, students do not vote because they are ashamed to be exposed to an invalid answer. The application, on the other hand, since it is anonymous and individual, allows more students to vote and this improves the overview that the teacher has of the class knowledge level. This can be seen as an important element for formative evaluation, "in order to adapt its pedagogical action to the processes and the learning problems observed in students" since it allows detecting difficulties presented by students in the understating of certain topics.

In order to build this solution, it is necessary to use the RPi as a server and set-up the whole system in a particular manner. The details on how this was achieved are in the next section.

Installation of Complete System

System consists of Raspberry pi 3 model B+, Its power supply, ethernet cable and a laptop. It creates its own local network Access point to which all other mobile device can connect. We are using Node-red programming tool for designing a classroom dashboard. Following steps have been followed during the development of the project.

- Installation of Operating System (OS) on the Raspberry Pi
- Basic configurations of Raspberry Pi such as setup of LAN, SSH, VNC, local time zone etc.
- Installation and set up of few software such as PUTTY ssh , VNC viewer on laptop for virtual connection with Raspberry Pi.
- Find IP address of ethernet eth0
- Setup wireless network of Raspberry Pi
- Install Node-RED
- Set up wireless network Access point
- Dashboard design on Node-RED

Installation of Operating System (OS) on the Raspberry Pi

Your Raspberry Pi needs an operating system to work. Raspberry Pi OS (previously called Raspbian) is official supported operating system. Raspberry Pi Imager is the quick and easy way to install Raspberry Pi OS and other operating systems to a microSD card, ready to use with your Raspberry Pi. Download and install Raspberry Pi Imager to a computer with an SD card reader. Put the SD card you'll use with your Raspberry Pi into the reader and run Raspberry Pi Imager.

Set up Raspberry Pi

With the new update, whenever a new Raspbian image is booted for the first time, a simple setup wizard runs automatically to walk you through the basic setup operations.

Localisation

The localisation settings you can access via the main Raspberry Pi Configuration application are fairly complex and involve making separate settings for location, keyboard, time zone, and WiFi country. The first page of the wizard should make this a little more straightforward — once you choose your country, the wizard will show you the languages and time zones used in that country.

Other Settings

The next pages in the wizard will walk you through changing your password, connecting to the internet, and performing an initial software update to make sure you get any patches and fixes that may have been released since your Raspbian image was created.

On the last page, you will be prompted to reboot if necessary. Once you get to the end of the wizard, it will not reappear when your Pi is booted. (If you do want to use it again for some reason, just run it manually by typing "sudo piwiz" into a terminal window and pressing Enter.)

Ethernet Connection

If your PC has a spare Ethernet port or you have an Ethernet-to-USB dongle, you can use a network cable to go directly from your Pi to your computer. Just make sure that you have Bonjour installed on your PC and SSH enabled on the Pi. Then, you can just connect the two devices over Ethernet.

Connecting via SSH from Windows

Use the PuTTy terminal emulator to access the Pi's linux shell from a Windows based computer. PuTTy will allow for running SSH, after downloading, follow the instruction on this page to log in to the Pi.

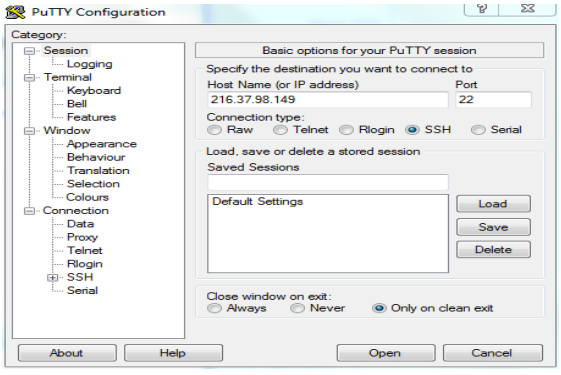

Fig.3 PuTTy display

- Download & install the PuTTy application.
- Enter the Pi's ip address in the Host Name Box on port 22
- Select SSH as connection type.
- Click Open button
- Accept the Server's key finger print
- Login as user pi with the password raspberry by default

VNC Viewer

VNC (Virtual Network Computing) is free for non-commercial use and built into the Raspbian operating system. With this, you can access Raspberry Pi remotely from any other computer, tablet, or smartphone, either on your home network, or via the internet.

Install Node-Red

Running the following command will download and run the script:

bash <(curl -sL https://raw.githubusercontent.com/node-red/linux-installers/master/deb/update-nodejs-and-nodered)

This script will:

- Remove the existing version of Node-RED if present.
- If it detects Node.js is already installed, it will ensure it is at least v12. If less than v12 it will stop and let the user decide whether to stay with Node-RED version 1 - or upgrade Nodejs to a more recent LTS version. If nothing is found it will install the current Node.js LTS release using the NodeSource package.
- Install the latest version of Node-RED using npm.
- Optionally install a collection of useful Pi-specific nodes.
- Setup Node-RED to run as a service and provide a set of commands to work with the service.

1) Running as a service

The install script for the Pi also sets it up to run as a service. This means it can run in the background and be enabled to automatically start on boot. The following commands are provided to work with the service:

- node-red-start - this starts the Node-RED service and displays its log output. Pressing Ctrl-C or closing the window does *not* stop the service; it keeps running in the background
- node-red-stop - this stops the Node-RED service
- node-red-restart - this stops and restarts the Node-RED service
- node-red-log - this displays the log output of the service

You can also start the Node-RED service on the Raspberry Pi OS Desktop by selecting the Menu -> Programming -> Node-RED menu option.

2) Opening the editor

Once Node-RED is running you can access the editor in a browser. If you are using the browser on the Pi desktop, you can open the address: http://localhost:1880.
When browsing from another machine you should use the hostname or IP-address of the Pi: http://<hostname>:1880. You can find the IP address by running hostname -I on the Pi.

Node-Red Dashboard

Node-RED Dashboard is a module that provides a set of nodes in Node-RED to quickly create a live data dashboard.

1) Installing Node-RED Dashboard

- To install the Node-RED Dashboard run the following commands:

pi@raspberry:~ $ **node-red-stop**
pi@raspberry:~ $ **cd ~/.node-red**
pi@raspberry:~/.node-red $ **npm install node-red-dashboard**

- Then, reboot your Pi to ensure that all changes take effect on Node-RED software:

pi@raspberry:~ $ **sudo reboot**

2) Creating a UI (User Interface)

- In this section we're going to show you how to create your UI (User Interface) in Node-RED. To open the Node-RED UI, type your Raspberry Pi IP address in a web browser followed by **:1880/ui** as shown below:
- http://Your_RPi_IP_address**:1880/ui**
- At the moment your dashboard is empty because we haven't added anything to the dashboard yet.

3) The Dashboard Layout

- Open another tab in your browser to access Node-RED with:
- http://Your_RPi_IP_address**:1880**
- Scroll down on the nodes section. You'll see you have a set of nodes called **dashboard** as shown in the following figure:

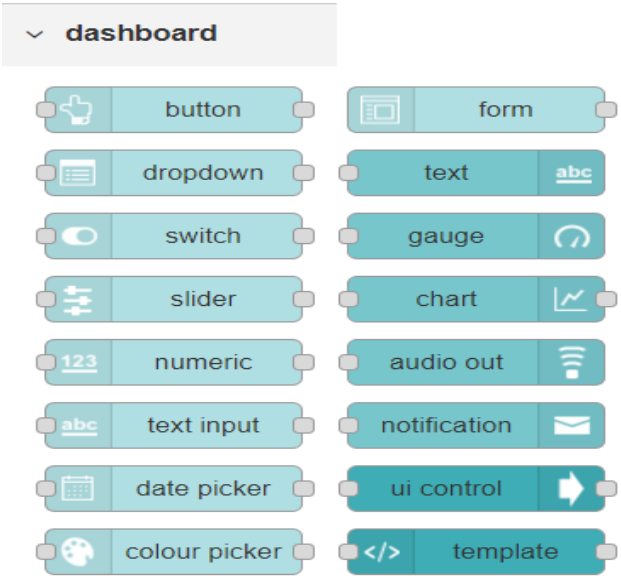

Fig. 4 Dashboard display

FunctionalTest

For functional test, Raspberry Pi board, One Laptop or PC and one SMARTPHONE are required. Followings steps are followed for functional testing of project:

- Connect Adapter to Raspberry Pi board.
- Connect Ethernet cable to laptop & RPi board.
- Switch on power supply.
- Wait for Stabilization.

- Open "putty "
- Enter Host name and fill IP address as: 169.254.197.156
- Click "Open"
- Login as : Pi
- Enter Password: raspberry
- Minimise this DOS window, never close.
- Open “VNC viewer"
- Go to "File”
- Go to New Connection.
- Enter VNC Server IP Address as given above.
- Give the name.
- Open this new connection.
- Enter User Name: Pi, Password: raspberry
- VNC Viewer Desktop opens.
- Open “terminal” icon.
- DOS window opens
- Enter “node-red-Start”
- Minimise DOS window. Don't close.
- Click on “web browser” icon.
- Enter “169.254.197.156: 1880” (Program) (For server)
- For another window- Enter “169. 254.197.156: 1880 / ui" (Dashboard) (For clients) – Address for use of students in their Smartphones.

UI interface for students to participate in the test is displayed as follows:

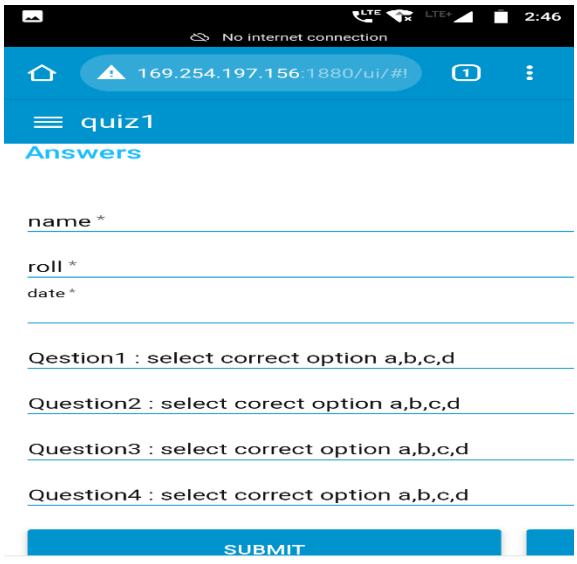

Fig. 5 SMARTPHONE display

Students can submit their details along with answers.

Relay Control Module

In this project, a Relay Control Module is also implemented. This can be used by the teacher to control the electric appliances of the classroom remotely. The relay module used in this project has a total of 6 interfaces, of which the normally open interface NO pin is responsible for connecting with the live wire of the electric lamp, and the COM pin is connected to its neutral line. Furthermore, the DC +5V takes positive power supply and the DC -5V is connected with the negative pole. The hooded jumper of this relay module is connected with the HIGH pin as a short circuit, in order to achieve a high trigger which has achieved the control of the relay pull. Furthermore, the IN pin accesses one of the GPIO interface of Raspberry Pi, and through the Python statement: GPIO.output (13,GPIO.HIGH),that means the 13th GPIO will produce a high level to control the relay’s pull-in, then the light will be lit.

IV. Conclusions and Future Work

Raspberry Pi (RPi) is a portable (small size) and cheap solution that allows developing a wide variety of applications. It is reflected from what is stated in this article, that once the desired solution is implemented in one RPi, it is really easy to replicate it in others RPi just by copying the SD card image. Students can access the form without the need of installing an application in their devices and accessing through Wi-Fi. Internet access is not required since the RPi works as access server creating its own Wi-Fi network. It is important to highlight that this is an autonomous solution since it does not require an Internet connection or any existing network infrastructure, so it can be used in any context, becoming ideal for places without Internet access. In institutions where Internet connectivity is permanent, it is possible that the network is overflowed due to a large number of simultaneous clients. This solution makes each class

connect to its own network and server, avoiding these problems and reducing the connectivity and network infrastructure costs. Although this article presents the proposal of making questionnaires, as future work the possibility of adding new resources arise for offering more options to the users. One possible resource is using RPi as file server where that the teacher can connect a USB drive to the RPi and share the contents of a specific folder with the students, using their mobile devices. This is the beginning of the evaluation for incorporating other didactic resources. The importance of exposing this type of work is not only to provide evidence of the importance of using ICTs in the classrooms but also that other colleagues can replicate this experience with a low-cost solution.

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